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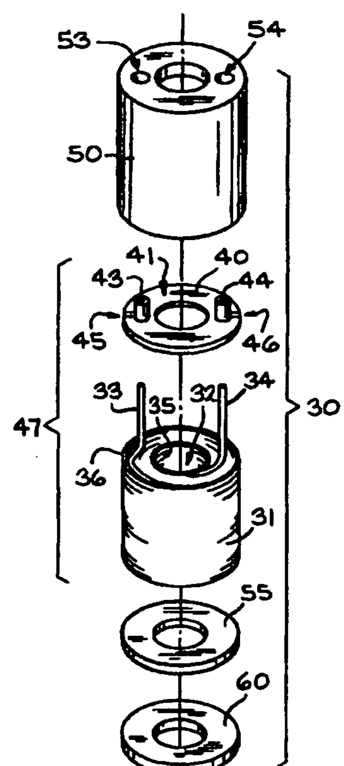
(54) Title: BOBBINLESS SOLENOID COIL

(57) Abstract

A bobbinless coil (30) for a solenoid valve having at least one free standing wire termination (33, 34). An end cap (40) having at least one terminal post (43, 44) is adjacent to one end of the coil with the post receiving and supporting the free standing wire termination.



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TITLE

BOBBINLESS SOLENOID COIL

BACKGROUND OF THE INVENTION

This invention relates in general to solenoid valves for anti-lock brake systems and in particular to a bobbinless solenoid coil.

An Anti-lock Brake System (ABS) is often included as standard equipment on new vehicles. When actuated, the ABS is operative to control the operation of some or all of the vehicle wheel brakes. A typical ABS includes a plurality of solenoid valves mounted within a control valve body and connected to the vehicle hydraulic brake system. Usually, a separate hydraulic source, such as a motor driven pump, is included in the ABS for reapplying hydraulic pressure to the controlled wheel brakes during an ABS braking cycle. The pump is typically included within the control valve body while the pump motor is mounted upon the exterior of the control valve body.

An ABS further includes an electronic control module which has a microprocessor. The control module is electrically coupled to the pump motor, a plurality of solenoid coils associated with the solenoid valves and wheel speed sensors for monitoring the speed and deceleration of the controlled wheels. The control module is typically mounted upon the control valve body to form a compact unit which is often referred to as an ABS electro-hydraulic control unit.

During vehicle operation, the microprocessor in the ABS control module continuously receives speed signals from the wheel speed sensors. The microprocessor monitors the speed signals for potential wheel lock-up conditions. When the vehicle brakes are applied and the microprocessor senses an impending wheel lock-up condition, the microprocessor is operative to actuate the pump motor and selectively operate the solenoid valves in the control unit to cyclically relieve and reapply hydraulic pressure to the controlled wheel brakes. The hydraulic pressure applied to the controlled wheel brakes is adjusted by the

operation of the solenoid valves to limit wheel slippage to a safe level while continuing to produce adequate brake torque to decelerate the vehicle as desired by the driver.

Referring now to Fig. 1, there is shown a sectional view of a typical ABS solenoid valve 10 mounted upon an ABS control valve body 11. The valve 10 includes an axially shiftable armature 12 which is biased in an upward direction by a spring 13 such that a ball valve, generally represented by a reference numeral 14, is maintained in a normally open position. The ball valve 14 cooperates with a valve seat member 15 which is mounted in the valve body 11. The armature 12 is slideably disposed within a valve sleeve 16 having a closed end. A solenoid coil 20 is carried by the valve sleeve 16 and surrounds the armature 12. The coil 20 is enclosed by a metal flux return casing 21. An annular flux ring 22 is disposed in the open end of the flux return casing 21. The flux return casing 21 and flux ring 22 complete a magnetic flux path which passes through the armature 12 and the valve seat member 15.

The solenoid coil 20 is of conventional design, comprising a winding 23 formed from multiple turns of an insulated magnet wire having a round cross section, such as #28 1/2 magnet wire. The coil wire is helically wound upon a plastic bobbin 24. A pair of terminal pin supports 25 extend in an axial direction from the top of the bobbin 24. Each of the supports 25 is molded over a terminal pin 26. An end 27 of the coil winding wire is wound around the base of each of the terminal pins 26 and soldered thereto. The pins 26 are electrically coupled to the ABS microprocessor.

When it is necessary to actuate the valve 10 during an anti-lock braking cycle, an electric current is supplied through the terminal pins 26 to the coil 20. The current establishes a magnetic field in the armature 12 which pulls the armature 12 in a downward direction, closing the ball valve 14. When the current is interrupted, the magnetic field collapses, allowing the spring 13 to return the armature 12 to its original position, thereby reopening the ball valve 14. An ABS control unit also typically includes other solenoid valves, such as normally closed

solenoid valves (not shown), which have structures similar to the normally open valve 10 described above.

SUMMARY

This invention relates to bobbinless solenoid coils for ABS solenoid valves and a method for making such coils.

A solenoid valve is actuated by a magnetic field generated by a solenoid coil when an electric current flows through the coil. For serviceability, the solenoid coils are typically located external to the ABS control valve body in a control module which can be removed from the control valve body without opening the hydraulic brake circuit of the vehicle. Accordingly, valve sleeves containing the valve armatures extend from the valve body and into the armature coils. Thus, the total volume required by the ABS electro-hydraulic control unit is a function of the size of the solenoid coils. It would be desirable to reduce the solenoid coil size to allow a corresponding reduction in the ABS electro-hydraulic control unit size.

The present invention contemplates reducing the size of solenoid valve coils by eliminating the coil bobbin. For a solenoid coil formed from helically wound wire, the strength of the magnetic field is directly proportional to the number of turns of wire in the coil and the magnitude of the current drawn by the coil. Elimination of the bobbin allows a reduction in the solenoid coil diameter and a corresponding reduction in the diameter of the coil winding wire without reducing the magnetic field strength. Also, the solenoid coil volume is a function of the square of the diameter of the wire forming the coil while the magnitude of the current drawn by the solenoid coil is a function of the diameter of the coil wire raised to the fourth power. Accordingly, reduction of the wire diameter should allow a significant reduction in the size of the coil and the amount of power required to energize the coil. Alternately, a bobbinless coil having the same size as a conventional coil wound upon a bobbin would produce a stronger field for the same amount of electric current.

The present invention contemplates a coil for a solenoid valve comprising a winding having a plurality of turns of helically wound magnet wire and an adhesive coating binding the turns into a rigid structure. The winding includes an axial bore adapted to receive a valve sleeve of a solenoid valve. In the preferred embodiment, the adhesive coating is an epoxy. The winding is formed with at least one flexible terminal wire extending therefrom. A circular disc is adjacent to an end of the winding and has at least one terminal post extending in a generally perpendicular direction therefrom which supports the terminal wire. The terminal post can have an axial slot formed therein, the slot extending radially to an edge of the disc and receiving the terminal wire. Alternately, the terminal post can have an axial bore formed therethrough which receives the terminal wire.

A first layer of an electrically insulative material can be disposed upon the inner surface of the winding axial bore and a second layer of electrically insulative material can be disposed upon the outer periphery of the winding.

The winding and disc are disposed within a cylindrical flux casing having a closed end and an open end, the closed end including at least one aperture formed therethrough. The terminal post and terminal wire extend through the flux casing arpeture. A resilient washer is disposed in the open end of the flux casing adjacent to the end of the winding. A circular flux ring also is disposed in the open end of the flux casing adjacent to the resilient washer, the flux ring being secured to the flux casing to retain the winding and disc within the flux casing.

The present invention also contemplates a method for forming a coil for an ABS solenoid valve which includes the steps of providing a winding mandrel and helically winding magnet wire upon the mandrel to form a coil winding. The magnet wire is coated with a thermally cured adhesive, such as an epoxy. An electric current is passed through the winding while the winding is on the mandrel. The electric current heats the wire to initially set the adhesive. The winding is then removed from the mandrel and placed in a curing oven. The

winding is baked in the curing oven to completely set the adhesive to bond the individual tuns of the coil winding together to form a rigid structure.

The coil winding is formed having at least one flexible terminal lead wire extending in an axial direction from an end of the coil. Additionally, prior to winding the wire upon the mandrel, a first layer of an electrically insulative material can be applied to the mandrel; and, subsequent to winding the wire, a second layer of an electrically insulative material can be applied to the periphery of the winding.

It is further contemplated that the method would include placing a circular disc adjacent to an end of the winding to form a coil assembly. The disc has at least one terminal post extending in a generally perpendicular direction therefrom which supports the terminal wire. The coil assembly is inserted into a flux casing having at least one arpeture formed therethrough, the terminal post and terminal wire extending through the flux casing arpeture.

Subsequent to inserting the coil assembly into the flux casing, a resilient washer is inserted into the open end of the flux casing and positioned adjacent to an end of the winding. A flux ring is then inserted into the open end of the flux casing and positioned adjacent to the resilient washer, the flux ring being secured to the flux casing.

Other objects and advantages of the invention will become apparent from the following detailed description of the invention and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a sectional view of an ABS solenoid valve which includes a solenoid coil in accordance with the prior art.

Fig. 2 is an exploded perspective view of a bobbinless solenoid coil in accordance with the invention.

Fig. 3 is a sectional view of the bobbinless coil shown in Fig. 2.

Fig. 4 is a sectional view of an alternate embodiment of the coil shown in Fig. 2.

Fig. 5 is a sectional view of another alternate embodiment of the coil shown in Fig. 2.

Fig. 6 is an exploded perspective view of another alternate embodiment of the coil shown in Fig. 2.

Fig. 7 illustrates alternate structures for an end cap included in the coil shown in Fig. 2.

Fig. 8 is a flow chart for a method for manufacturing the bobbinless coils shown in Figs. 2 through 4.

Fig. 9 illustrates a method for winding the bobinless coils shown in Figs. 2 through 7.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring again to the drawings, there is illustrated in Figs. 2 and 3 an improved solenoid coil 30 which has no bobbin. Components shown in Fig. 3 which are similar to components shown in Fig. 1 have the same numerical designators.

The bobbinless solenoid coil 30 includes a winding 31 having an axial bore 32 and a pair of free standing terminal wires 33 and 34. The winding 31 is helically wound from a continuous length of insulated solenoid magnet wire. As will be described below, the coil wires are rigidly bonded together with an adhesive. Accordingly, a plastic bobbin is not required to maintain the structure of the winding.

In the preferred embodiment, a first layer 35 of a commercially available poyimide tape, such as, for example, Kapton tape, is disposed upon the inner surface of the bore 32 and a second layer 36 of the same poyimide tape is wrapped around the periphery of the winding 31 to enhance the structural integrity thereof. While a polyimide tape is used in the preferred embodiment, it will be appreciated that other commercially available electrically insulating tapes

also can be used. Alternately, a thin plastic shield or sleeve (not shown) can be used instead of tape. It will appreciated that the first and second layers of tape 35 and 36 are optional, and the invention can be practiced without the tape layers.

A disc-shaped end cap 40 is located adjacent to the upper end of the winding 31. In the preferred embodiment, the end cap 40 is formed from plastic and has an aperture 41 formed through the center thereof. As shown in Fig. 3, the aperture 41 receives the end of the valve sleeve 16. The end cap 40 further includes a pair of terminal posts 43 and 44 which extend in a generally perpendicular direction from the top surface of the end cap 40. As shown in Figs. 2 and 3, the terminal posts 43 and 44 include axial slots 45 and 46, respectively, which extend radially from the center of the associated terminal post to the outer edge of the end cap 40. Each of the slots 45 and 46 receives one of the free standing terminal wires 33 and 34, respectively. The end cap 40 and winding form a winding assembly 47.

While slotted terminal posts 43 and 44 are illustrated in Figs. 2 and 3, it will be appreciated that the terminal posts also can be formed having axial bores extending therethrough, such as shown in Fig. 7A. For such an end cap, the terminal wires 33 and 34 would extend through the axial bores. The invention further contemplates that the winding assembly 47 can be encapsulated (not shown); however, this step is optional. The encapsulate would bond the end cap to the coil winding while protecting the winding.

A conventional cup-shaped steel flux casing 50 receives the winding assembly 47. A pair of terminal post apertures 53 and 54 are formed through the top end of the flux casing 50. Each of the terminal post apertures 53 and 54 receives one of the terminal posts 43 and 44, respectively. Thus, the terminal posts 43 and 44 guide the free standing terminal wires 33 and 34 through the flux casing apertures 53 and 54. Additionally, the terminal posts 43 and 44 support the terminal wires 33 and 34 while providing additional insulation and strain relief therefor.

The coil 30 also includes an elastic foam washer 55 disposed within the flux casing 50 adjacent to the lower end of the winding 31. The foam washer 55 provides a preload force upon the winding 31 to prevent relative movement between the winding 31 and other coil parts which potentially could cause winding wear and shorting. Alternately, an elastic O-ring (not shown) can be positioned adjacent to the lower end of the winding 31 or a layer of a elastometer (not shown), such as silicone rubber, can be applied to the lower end of the winding 31. Upon curing, the elastometer forms an elastic layer.

A steel flux ring 60 is disposed in the flux casing 50 below the foam washer 55 to provide a return path for the magnetic flux generated by the winding 31. The flux ring 60 also retains the other coil components within the flux casing 50. In the preferred embodiment, the flux ring 60 is retained in the lower end of the flux casing 50 by an interference fit; however, the flux ring 60 also can be secured within the casing 50 by spot welding, dimples or swaging.

As shown in Fig. 3, the coil 30 is mounted upon a Printed Circuit Board (PCB) 65 which has electrical traces (not shown) deposited upon its upper surface. The PCB 65, which is included in an ABS electronic control module (not shown), carries electronic logic and switching components for energizing the coil 30. The PCB 65 has a pair of terminal post openings 67 and 68 formed therethrough which correspond to the coil terminal posts 43 and 44. The coil terminal posts 43 and 44 and associated terminal wires 33 and 34 extend through the PCB terminal post openings 67 and 68, respectively. The terminal wires 33 and 34 are formed into semi-circular loops 69 and 70 with their free ends soldered to the electrical traces on the surface of the PCB 65. The terminal wire loops 69 and 70 allow lateral movement of the coil 30 relative to the PCB 65 to accommodate manufacturing tolerances of the assembled control valve (not shown).

As best seen in Fig. 3, the coil 30 is associated with a solenoid valve 75. The bore of the coil 30 receives the sleeve 16 which contains a solenoid valve armature 12. The armature 12 is urged in an upward direction in Fig. 3 by a

spring 13. A valve ball 14 is mounted upon the bottom surface of the armature 12. The valve ball cooperates with a valve seat 15 which is mounted in an ABS control valve body 11.

An alternate embodiment 80 of the bobbinless coil is illustrated in Fig. 4. Components in Fig. 4, which are the same as components in Fig. 3 have the same numerical designators. The outside diameter of the solenoid coil 80 is increased while the height of the coil 80 is decreased from the corresponding dimensions of the coil 31 shown in Fig. 3. This allows both the coil 80 in Fig. 4 and the prior art coil 20 to produce the same magnetomotive forces with the same size wires. Additionally, if the same number of turns are used on both coils 20 and 80, the coils 20 and 80 will draw the same current, but the coil 80 in Fig. 4 will have a height which is less than the height of the prior art coil 20. If the length of the coil 80 is increased from the minimum height just described, the magnetomotive force of the lengthened coil will remain constant, but the current drawn by the coil will decrease in proportion to the ratio of length increase to the initial length.

The coil 80 includes an end cap 81 which includes a pair of terminal posts 83 and 84 having axial slots 85 and 86, respectively, formed therein. As best seen in Figs. 4A and 4B, a bead 87 is formed in one slot 85 and an indention 88 formed in the other slot 86. Upon inserting the terminal wires 33 and 34 into the slots 85 and 86, the wires 33 and 34 are pressed against the bead 87 and into the indention 88 to form a small kink 89 in each wire. The kinks 89 cooperate with the bead 87 and the indentation 88, respectively, to secure the wires 33 and 34 within the slots 85 and 86.

Additionally, a first bead 90 of an adhesive is disposed between the end cap 81 and the inside surface of the top of the flux casing 50 to secure the end cap 81 within the casing 50. A second bead 91 of adhesive is disposed between the lower end of the winding 31 and the flux ring 60 to prevent relative movement between the winding 31 and the other coil components. Accordingly, the foam washer 55 described above can be omitted from the coil 80. The

adhesive forming the beads 90 and 91 can be a contact adhesive or an adhesive that is thermally activated when the coil wire is bonded together.

Another alternate embodiment 95 of the bobbinless coil is illustrated in Fig. 5. Components in Fig. 5, which are the same as components in Figs. 3 and 4 have the same numerical designators. As shown in Fig. 5, the bobbinless coil 95 includes an end cap 96 which has terminal posts 97 and 98 overmolded in the flux casing apertures 53 and 54. The overmolded terminal posts 97 and 98 retain the end cap 96 in the flux casing 50. Similar to the end cap structures described above, a pair of slots 99 and 100 are formed in the posts 97 and 98, respectively. Each of the terminal post slots 99 and 100 receives one of the free standing terminal wires 33 and 34.

While the terminal posts 97 and 98 are shown as being overmolded on the flux casing 50 in Fig. 5 and a bead of adhesive 90 is used to retain the end cap 81 in the flux casing 50 in Fig. 4, it will be appreciated that other structures or methods can be used to attach the end cap to the flux casing. For example, the terminal posts can be press fit into the flux casing apertures (not shown). Alternately, spring clips (not shown), which engage the flux casing, can be formed upon the terminal posts.

A portion of each of the free standing terminal wires 33 and 34 is formed into semi-circular loops 101 and 102, respectively. The loops 101 and 102 provide strain relief and accommodate alignment tolerances between the PCB 65 and the solenoid valve sleeve 16. The end of each of the terminal wires 33 and 34 extends 12 through an associated aperture 103 and 104, respectively, which is formed through the PCB 65. The ends of the terminal wires 34 and 34 are retained in the apertures 103 and 104 and electrically connected to conductive traces (not shown) on the upper surface of the PCB 65 by solder 105. It will further be appreciated that the connections between the bobbinless coils and the PCB 65 described and illustrated above are exemplary and that the invention can be practiced with other structures than those shown for electrically connecting the bobbinless coils to the other components of the ABS.

Another embodiment of the structure for the bobbinless coil is shown at 110 in Fig. 6. Again, components of the coil 110 which are the same as components of the bobbinless coils described above have the same numerical designators. The coil 110 includes a coil winding 31 and an end cap 111 having slotted terminal posts 112 and 113 which extend from the inner and outer circumference, respectively, of the end cap 111. As shown in Fig. 6, the exterior of the coil winding 31 and the outer edge of the end cap 111 is wrapped with a layer of adhesive backed Kaptan tape 115 The upper edge of the Kaptan tape 115 is formed with a plurality of upper tabs 116. The upper tabs 116 are folded onto the upper surface of the end cap 111. Similarly, the lower edge of the Kaptan tape is formed with a plurality of lower tabs (not shown) which are folded onto the bottom surface of the winding 31. The upper tabs 116 retain the end cap 35 on the winding 31 to form a winding assembly 117 while the lower tabs protect the outer surface of the winding 31.

Similar to the coil 30 described above, the winding assembly 117 is disposed within a flux casing 118 with the terminal posts 113 and 112 and the associated terminal wires 33 and 34 extending axially through corresponding terminal post apertures in the flux casing 118. An elastic foam washer 55 is disposed in the open end of the flux casing 118 adjacent to the lower end of the winding assembly and a flux ring 60 is secured in the lower end of the casing 118. In an alternate embodiment of the coil structure shown in Fig. 6, the lower tabs of the Kapton tape 115 are folded over the foam washer 55 and retain the washer 55 on the coil winding 31 (not shown).

It will be appreciated that the terminal posts shown in Figs. 2 through 6 are illustrative of the invention and that the invention can be practiced with alternate structures for the end cap. Several alternate structures for the end cap are illustrated in Fig. 7. Fig. 7H corresponds to the end cap structure shown in Figs. 2 through 4. The other examples of end caps shown in Fig. 7 are intended to be illustrative and it will be appreciated that the invention can be practiced with other structures and positioning of the terminal posts than are shown in Fig. 7. It

will be noted that both slots and bores formed in the terminal posts are illustrated. Additionally, the invention contemplates that the slots could be formed having lateral tapers (not shown) for securing the terminal wires within the slots.

The end cap illustrated in Fig. 7G includes a pair of studs 120 and 121 which extend in a generally perpendicular direction from the top surface of the end cap. The invention contemplates that the studs extend through corresponding apertures formed though the top of a flux casing (not shown). The ends of the studs 120 and 121 are formed by a conventional method into rivet heads (not shown) to secure the end cap within the flux casing. It will be appreciated that if a winding is attached to the end cap as described above, the rivets will also secure the winding 31 within the flux casing.

While the invention has been illustrated by coils having a pair of terminal wires, it also will be appreciated that the invention may be practiced to form a coil with only one terminal wire and one terminal post extending through the flux return casing. The other end of the coil winding would be in electrical contact with the associated solenoid valve sleeve to provide an electrical return path through the control valve body.

The reduced diameter bobbinless coil 30, shown in Figs 2 and 3, provides a number of advantages over prior art coils. In the preferred embodiment, the diameter of the coil is reduced from 20.13 mm to 15.53 mm, which is a 23% reduction. Additionally the current drawn by the bobbinless coil is reduced from the current drawn by the prior art coils. In the preferred embodiment, the current draw is reduced by 22% while the control valve width can be reduced by up to 18.4 mm by reducing the spacing between the solenoid valves, subject to size reduction of other ABS components.

The reduced height bobbinless coil 80, shown in Fig. 4, provides the similar advantages. In the preferred embodiment, based only upon the coil, the valve height can potentially be reduced by up to 10.4 mm; however, this height reduction may be limited by the size of other ABS components to 3 to 4 mm.

This height reduction permits a corresponding reduction in the overall height of the ABS control valve.

It will be appreciated that while the invention has been illustrated by a reduced diameter coil 30 and a reduced height coil 80, the invention also contemplates other sizes of bobbinless coils which have not been specifically shown or described above. Thus, it would be possible to design a coil with both a reduced height and diameter which has dimensions falling between the extremes illustrated above. Such a coil would allow corresponding reductions in the height and width of the ABS control valve and may permit placement of the control valve in more advantageous locations on the vehicle.

Additionally, while the preferred embodiment of the invention has been described and illustrated for a bobbinless coil and an associated end cap having terminal posts, it also will be appreciated that the invention can be practiced for a bobbinless coil without the end cap (not shown). Such a coil would have the free standing terminal wires ends extending through the flux casing apertures. An optional adhesive bead could be disposed between the top end of the coil and the flux casing which would prevent relative motion therebetween. The adhesive bead also could extend into the flux casing apertures to prevent contact between the free standing terminal wires and the flux casing.

The present invention further contemplates a method for manufacturing bobbinless solenoid coils. The method is illustrated by the flow chart shown in Fig. 8. In functional block 130, a mandrel having an outside diameter which corresponds to the inside diameter of the coil is selected. The mandrel is mounted upon a high speed coil winding machine.

A layer of electrically insulative tape is wound upon the mandrel in functional block 131. In the preferred embodiment, a commercially available polyimide tape, such as Kapton tape is used; however, other tapes also can be used. If the coil is to include an interior plastic sleeve, the sleeve is positioned on the mandrel.

In functional block 132, the high speed coil winding machine helically winds insulated magnet wire upon the mandrel to form a solenoid coil. The magnet wire can be pre-coated with a thermo-setting epoxy before winding or the epoxy can be included in the wire insulative coating. Alternately, the wire can be passed through an epoxy dispenser as it is fed to the winding machine. The dispenser would apply a coating of the epoxy to the wire.

After the coil is wound, the wire is cut and the terminal wires are formed extending from one end of the coil and parallel to the coil axis, as indicated in functional block 133. In functional block 134, an outer layer of the same electrically insulative tape is wound over the periphery of the coil.

The terminal wires are connected to a power supply in functional block 135 and an electric current is passed through the coil. The heat generated by the current initially sets the epoxy. In functional block 136, the coil is removed from the mandrel.

The coil is placed in a curing oven in functional block 137 and baked to completely set the epoxy and bond the coil windings together to form a rigid coil.

In functional block 138, a coil assembly is formed by positioning an end cap adjacent to the end of the coil having the free standing terminal wires. The terminal wires are inserted through the end cap posts. Additionally, the coil can be encapsulated by dipping the coil assembly in a potting material; however, the encapsulation is optional. As the encapsulate cures, it will protect the winding while bonding the winding to the end cap.

In functional block 139, the coil assembly is inserted into a flux casing with the terminal wires and supporting end cap posts extending through associated flux casing apertures.

An elastic foam washer and steel flux ring are inserted into the open end of the flux casing in functional block 140. The flux ring is retained in the flux casing by a conventional method, such as, an interference fit, spot welding, dimples or swaging.

The present invention also contemplates an improvement in the winding

process as shown in Fig. 9. The improvement includes a winding end cap 145 which has a plurality of indentations 146 formed in the surface of its center aperture. The indentations 146 correspond to a plurality of retractable pins 147 carried by a mandrel 148 on a coil winding machine 149. To wind a coil, the pins 147 are retracted into the mandrel 148 and the end cap 145 placed upon the mandrel 148. The pins 147 are extended into the indentations 146 and cooperate therewith to secure the end cap 145 upon the mandrel 148. A length of epoxy coated magnet wire is wound upon the mandrel 148 to form a bobbinless winding 150. Terminal wires (one shown) are formed and inserted into the terminal posts. As described above, an electric current is passed through the winding 150 to fix the epoxy. The epoxy also bonds the end cap 145 to the end of the winding 150. The pins 147 are retracted into the mandrel 148 to allow removal of the winding and end cap assembly from the winding machine 149.

In accordance with the provisions of the patent statutes, the principle and mode of operation of this invention have been explained and illustrated in its preferred embodiment. However, it must be understood that this invention may be practiced otherwise than as specifically explained and illustrated without departing from its spirit or scope. For example, while the invention has been described as being included in an anti-lock brake system, it will be appreciated that the invention can also be applied to solenoid valves in other systems, such as , for example, traction control systems and vehicle stability systems. Additionally, it also will be appreciated that the structural details shown in one embodiment can be applied to the alternate embodiments. Thus, for example, the invention can be practiced with the foam washer 55 shown in Fig. 3 substituted for the beads of adhesive 90 and 91 shown in Fig. 4.

What is claimed is:

1. A coil for a solenoid valve comprising:

a winding having a plurality of turns of helically wound magnet wire which defines an axial bore, said bore adapted to receive a valve sleeve of a solenoid valve; and

an adhesive coating binding said turns into a rigid structure.

2. A coil according to claim 1 wherein said winding has at least one flexible terminal wire extending therefrom.

3. A coil according to claim 2 further including a circular disc which is adjacent to an end of said winding, said disc having at least one terminal post extending in a generally perpendicular direction therefrom, said terminal post supporting said terminal wire.

4. A coil according to claim 3 wherein said terminal post has an axial slot formed therein, said slot extending radially to an edge of said disc, said slot receiving said terminal wire.

5. A coil according to claim 3 wherein said terminal post has an axial bore formed therethrough, said bore receiving said terminal wire.

6. A coil according to claim 3 further including a cylindrical flux casing having a closed end and an open end, said closed end including at least one aperture formed therethrough, said winding and said disc being disposed within said flux casing with said terminal post and said terminal wire extending through said flux casing arpeture.

7. A coil according to claim 6 wherein said disc is adhesively secured within said flux casing.

8. A coil according to claim 6 wherein said disc is structurally attached to said flux casing.

9. A coil according to claim 6 further including a circular flux ring disposed in said open end of said flux casing adjacent to said winding, said flux ring secured to said flux casing to retain said winding within said flux casing.

10. A coil according to claim 9 also including a resilient material disposed between said flux ring said winding end.

11. A coil according to claim 3 wherein said adhesive coating is an epoxy.

12. A coil according to claim 3 wherein a first layer of an electrically insulative material is disposed upon the inner surface of said axial bore and a second layer of electrically insulative material is disposed upon the periphery of said winding.

13. A coil according to claim 3 further including an adhesive backed tape wound about the outer surface of said winding, said tape extending onto the surface of said disc and retaining said disc upon an end of said winding.

14. A coil according to claim 10 wherein the coil is mounted upon a solenoid valve which is included in an anti-lock brake system.

15. A method for forming a coil for an ABS solenoid valve comprising the steps of:

(a) providing a winding mandrel;

(b) helically winding magnet wire, which is coated with a thermally curable adhesive, upon the mandrel to form a coil;

(c) passing an electric current through the coil to initially set the adhesive;

(d) removing the coil from the mandrel; and

(e) curing the coil in an oven to completely set the adhesive to form a rigid coil.

16. A method as described in claim 15 wherein, subsequent to step (b), at least one flexible terminal lead wire is formed from an end of the coil winding wire, the lead wire extending in an axial direction from an end of the coil.

17. A method as described in claim 16 further including in step (b), prior to winding the wire upon the mandrel, applying a first layer of an electrically insulative material to the mandrel, and, subsequent to winding the wire, applying a second layer of an electrically insulative material to the periphery of the winding.

18. A method as described in claim 17 wherein, subsequent to step (e), a circular disc having at least one terminal post extending in a generally perpendicular direction therefrom is placed adjacent to an end of the winding with the terminal post supporting the terminal wire to form a coil assembly.

19. A method as described in claim 18 wherein the coil assembly is inserted into a flux casing having at least one arpeture formed therethrough, the terminal post and terminal wire extending through the flux casing arpeture.

20. A method as described in claim 19 wherein, subsequent to inserting the coil assembly into the flux casing, a resilient washer is inserted into the open end of the flux casing and positioned adjacent to an end of the winding and a flux ring is inserted into the open end of the flux casing and positioned adjacent to the resilient washer, the flux ring being secured to the flux casing.

21. A method as described in claim 17, wherein, subsequent to step (e), a circular disc is provided having at least one terminal post having a passageway formed therein, the terminal post extending in a generally perpendicular direction from the disc, the disc being secured in a flux casing with the terminal post extending through an aperture formed through the flux casing and further wherein the winding formed in steps (a) through (e) is inserted into the flux casing with the terminal wire extending through the passageway formed in the terminal post.

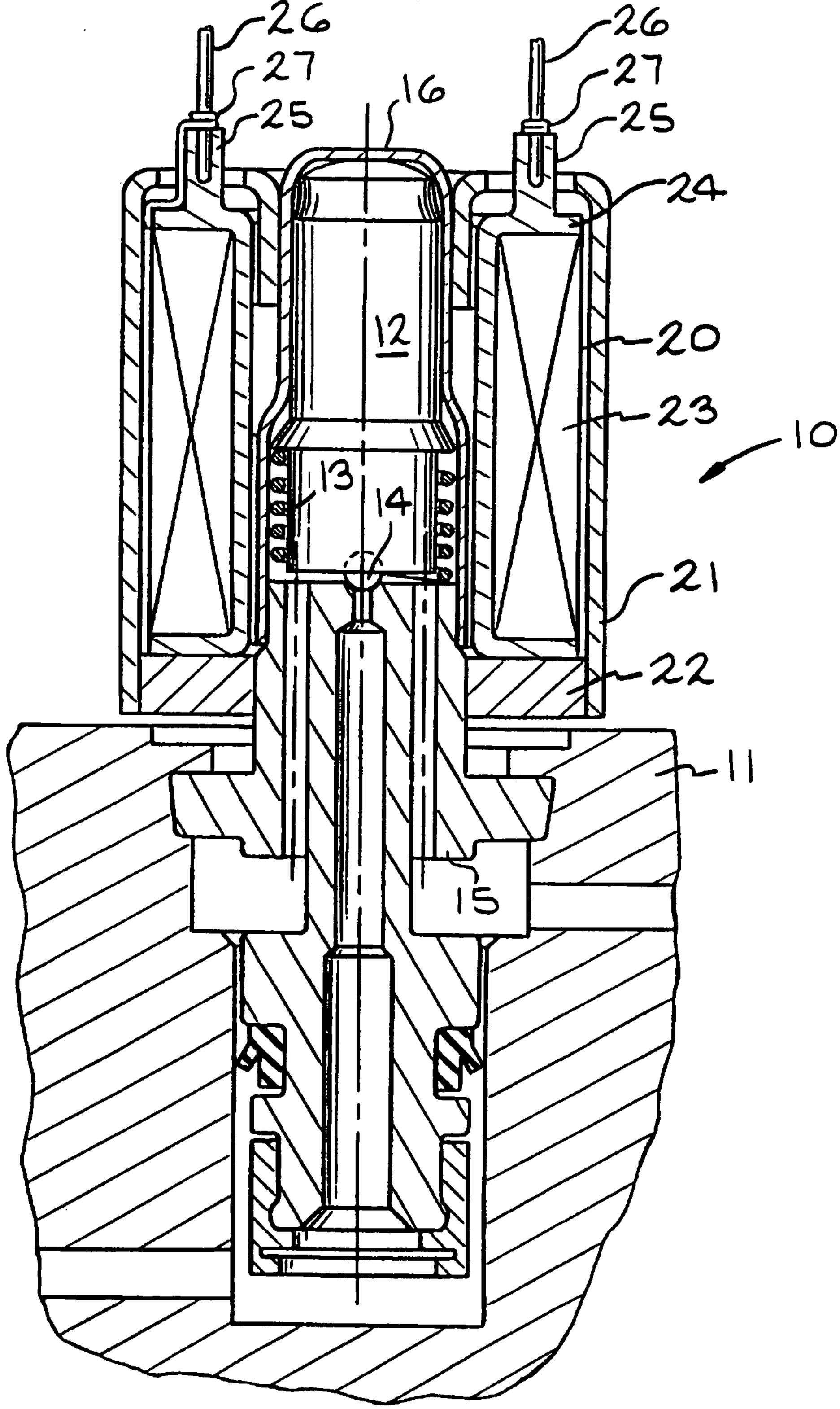

FIG. 1 PRIOR ART

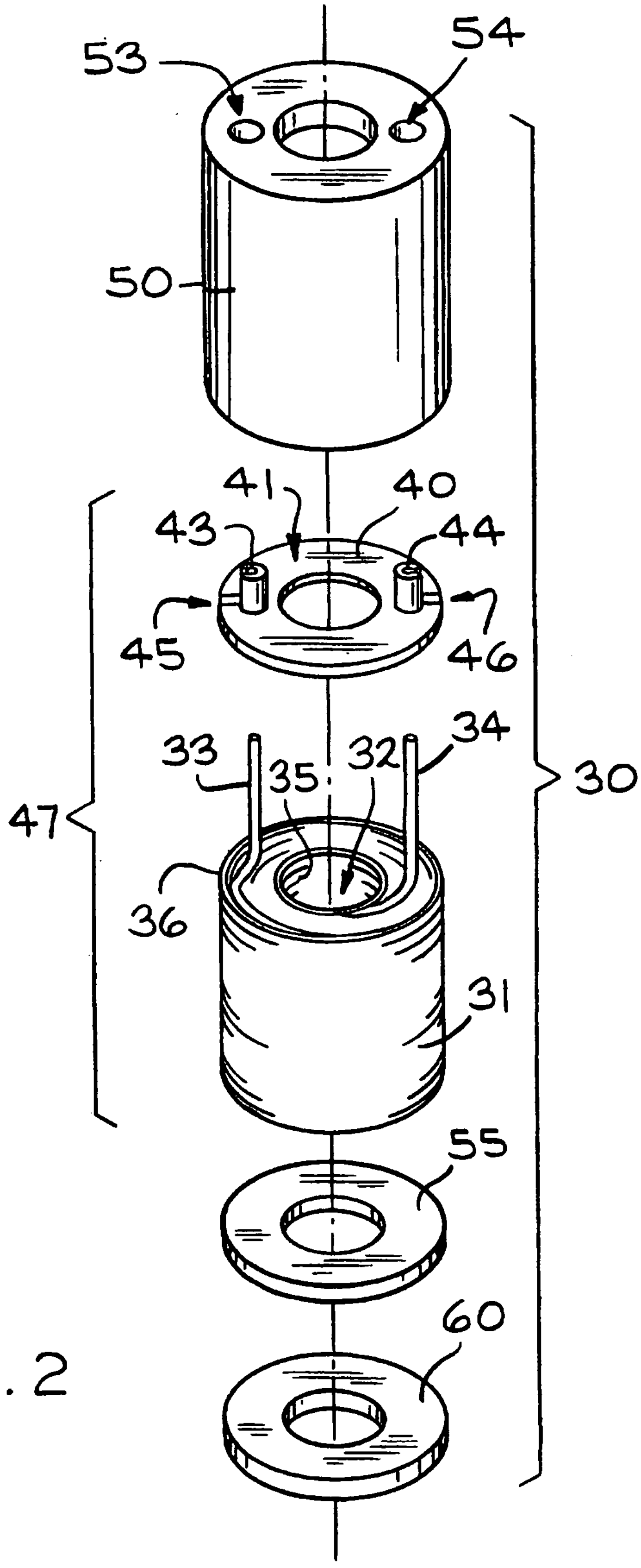

FIG. 2

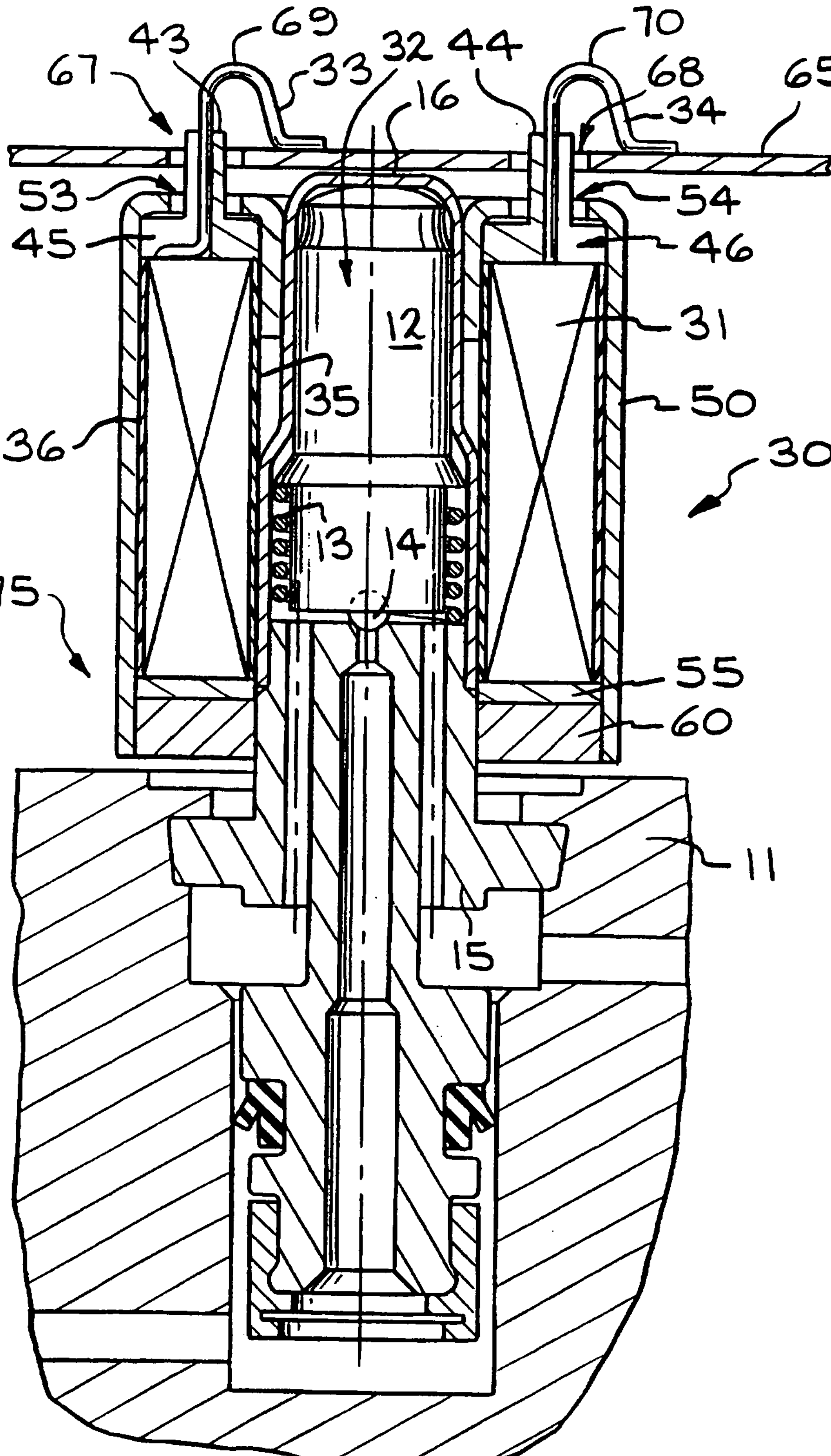

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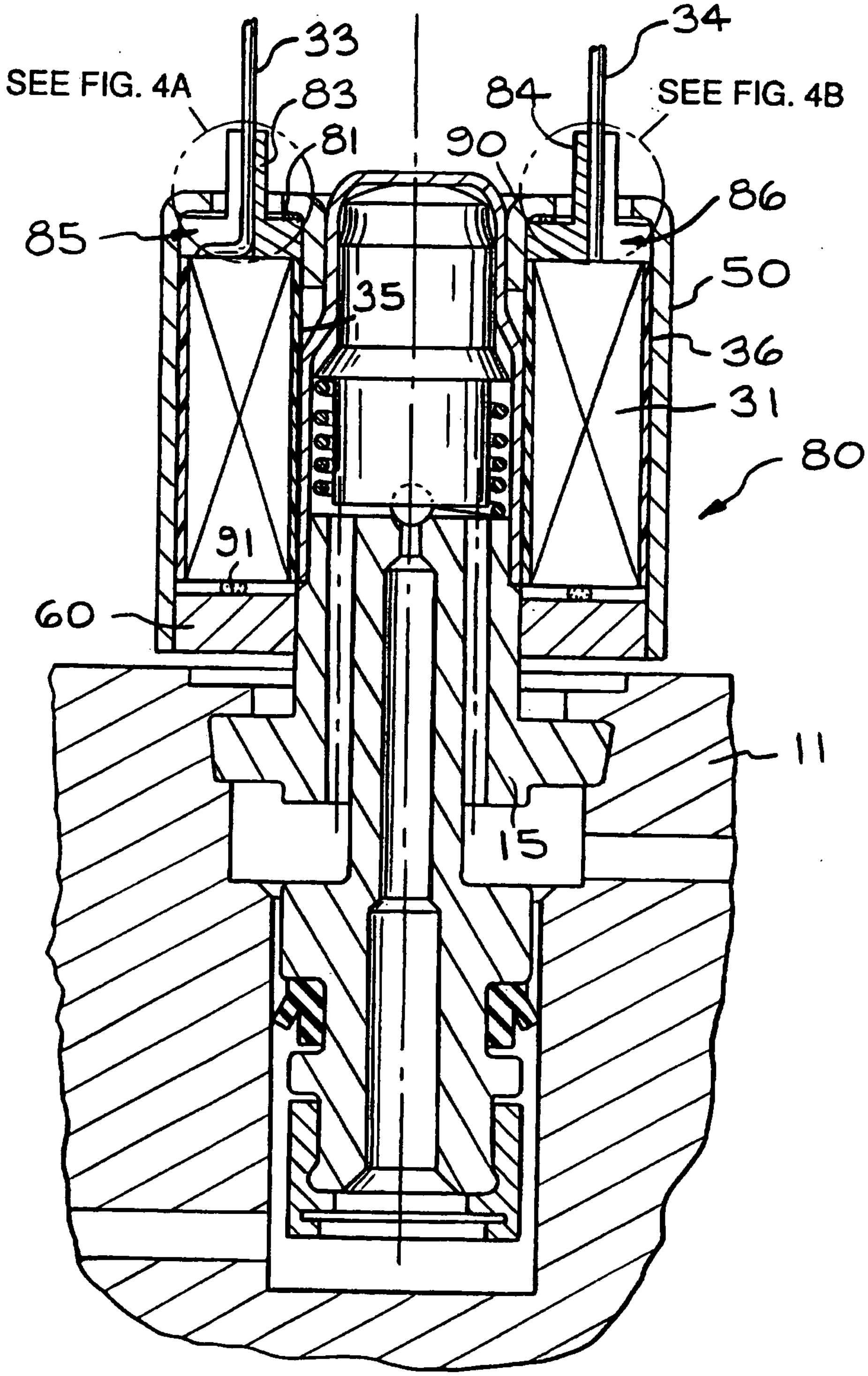
FIG. 3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SEE FIG. 4A
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SEE FIG. 4B
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FIG. 4

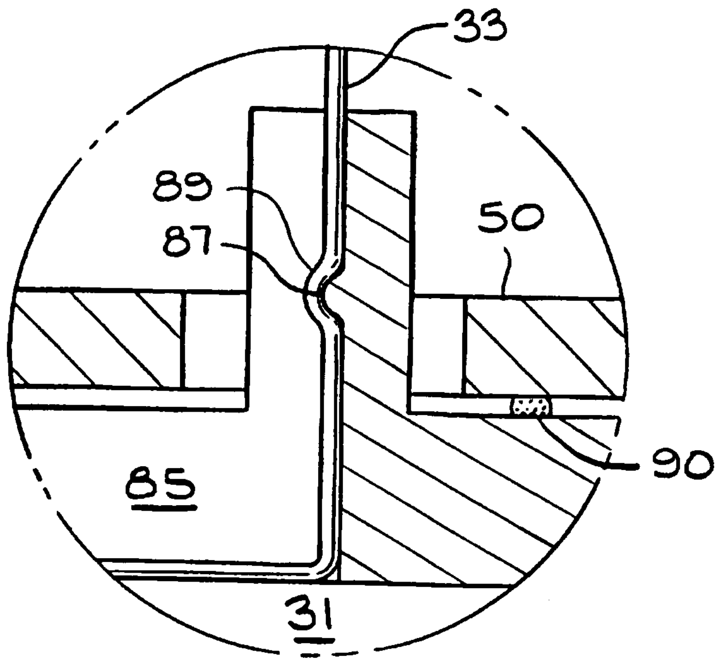

FIG. 4A

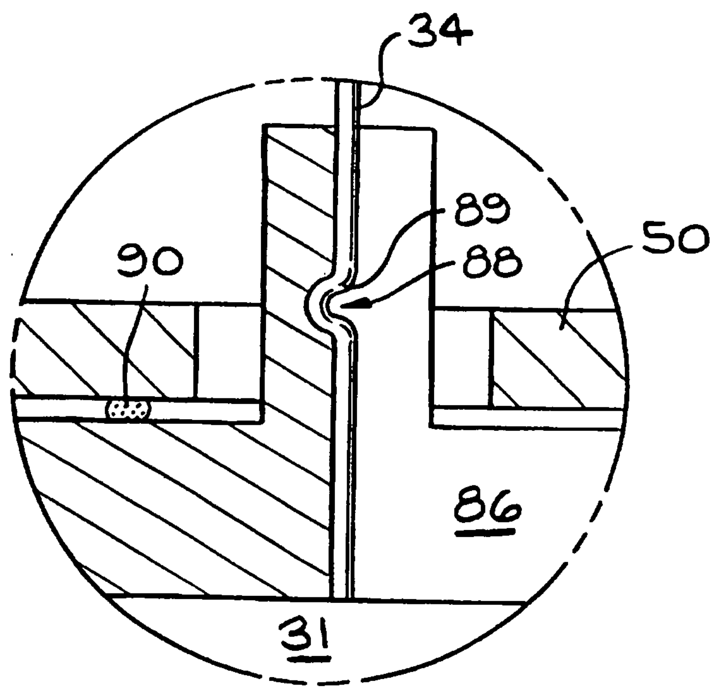

FIG. 4B

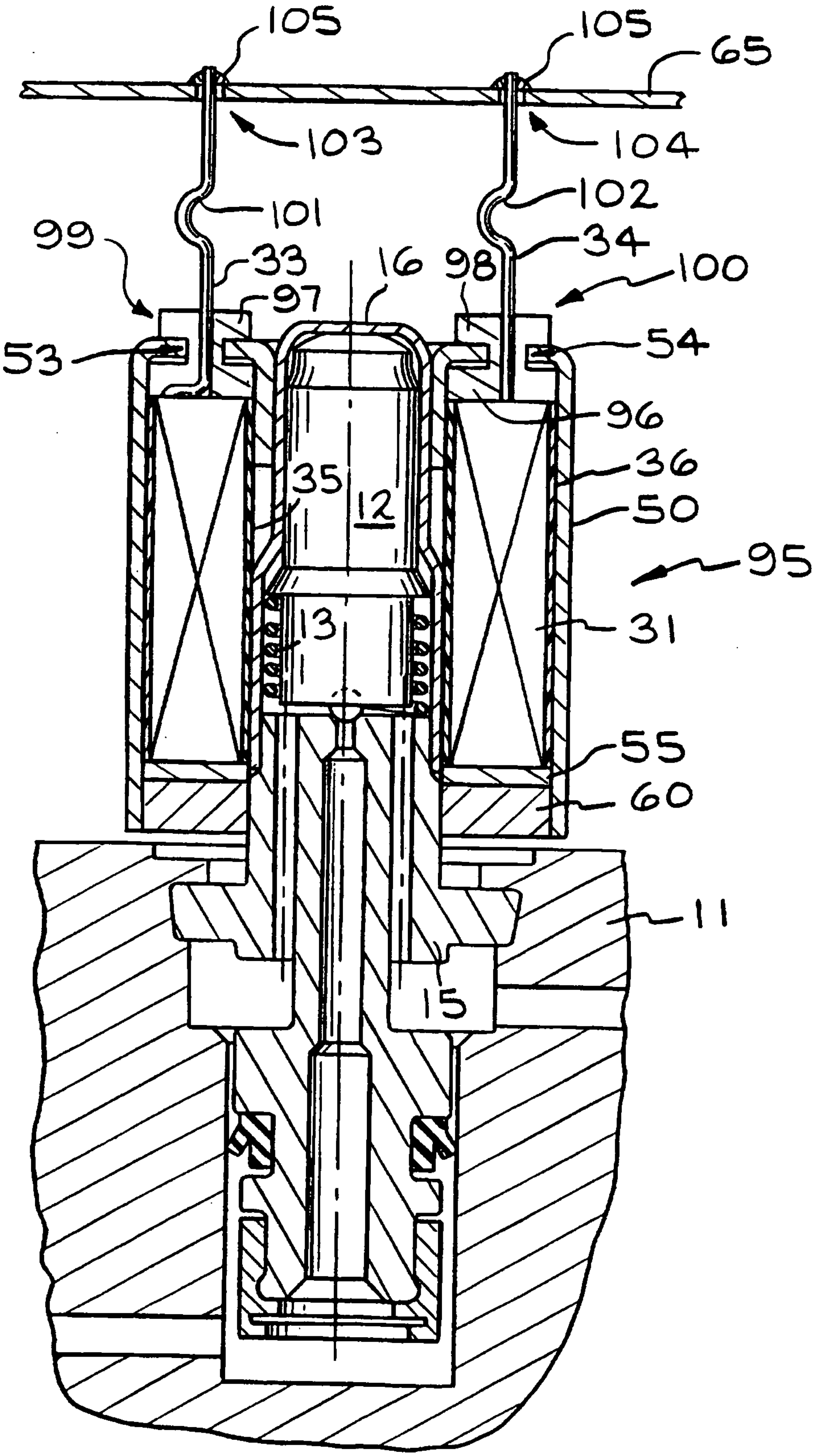
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FIG. 5

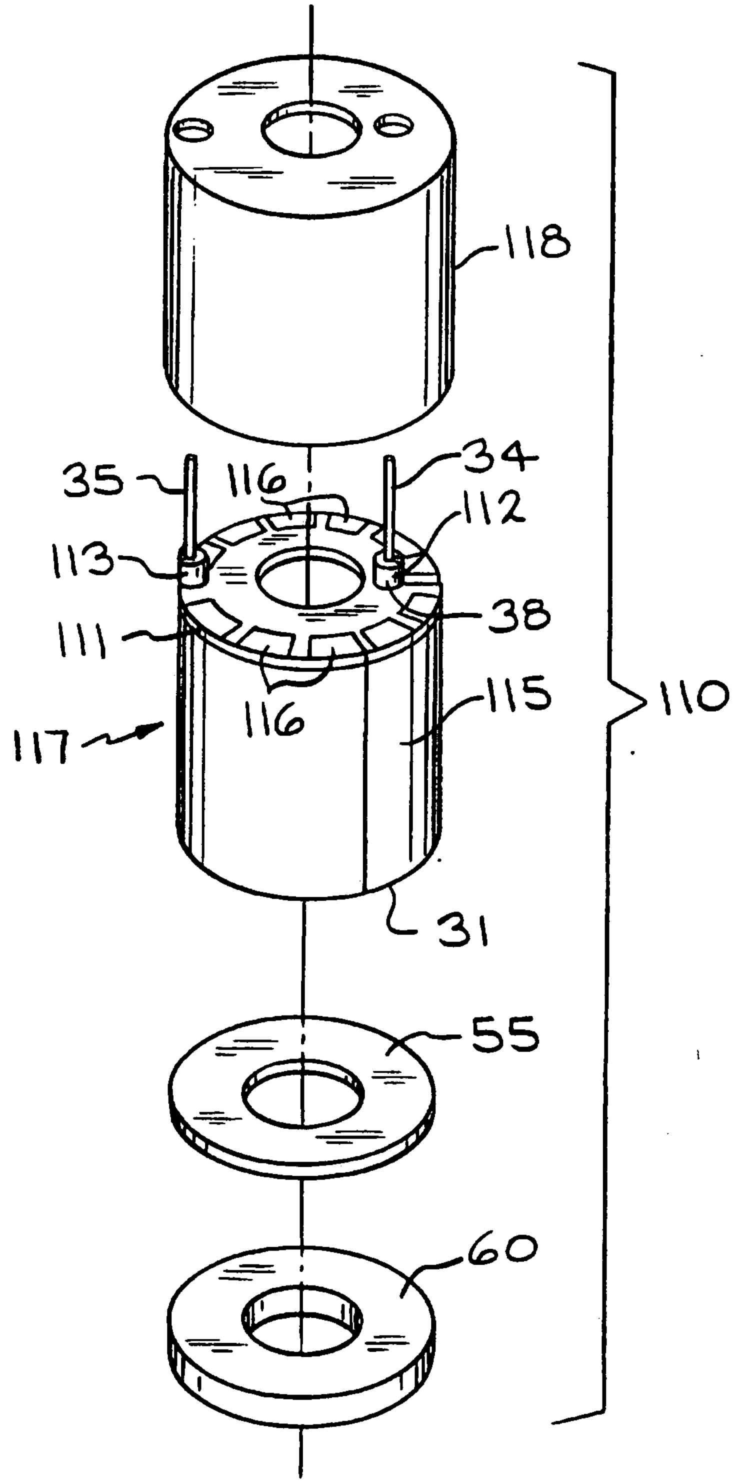


FIG. 6

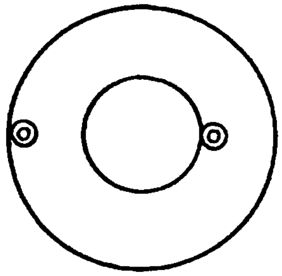


FIG. 7A

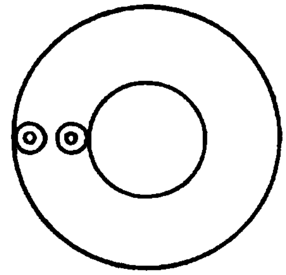


FIG. 7D

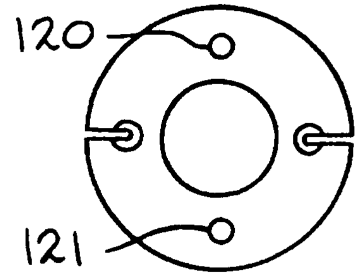


FIG. 7G

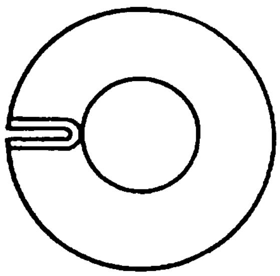


FIG. 7B

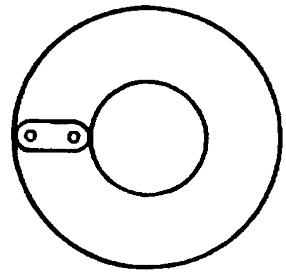


FIG. 7E

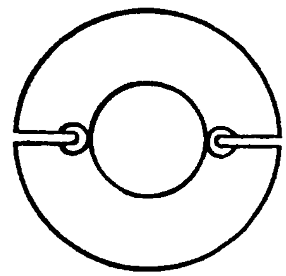


FIG. 7H

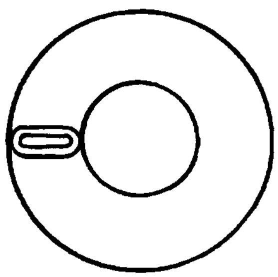


FIG. 7C

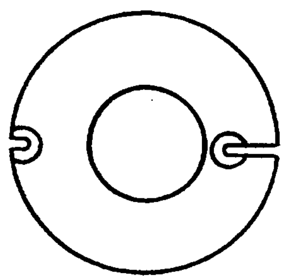
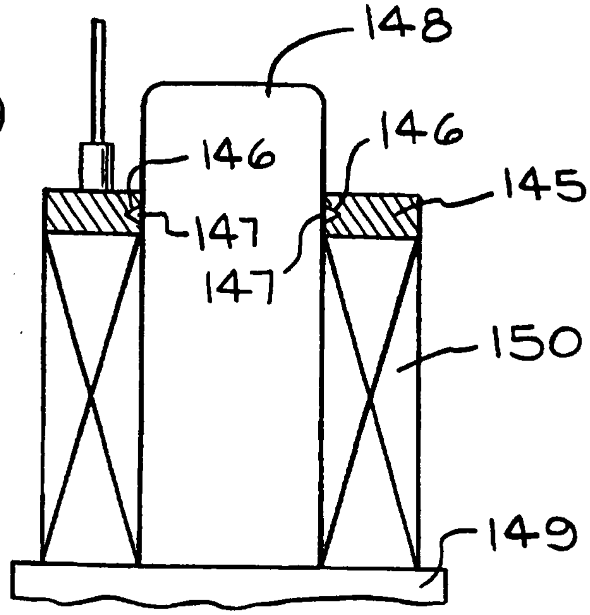
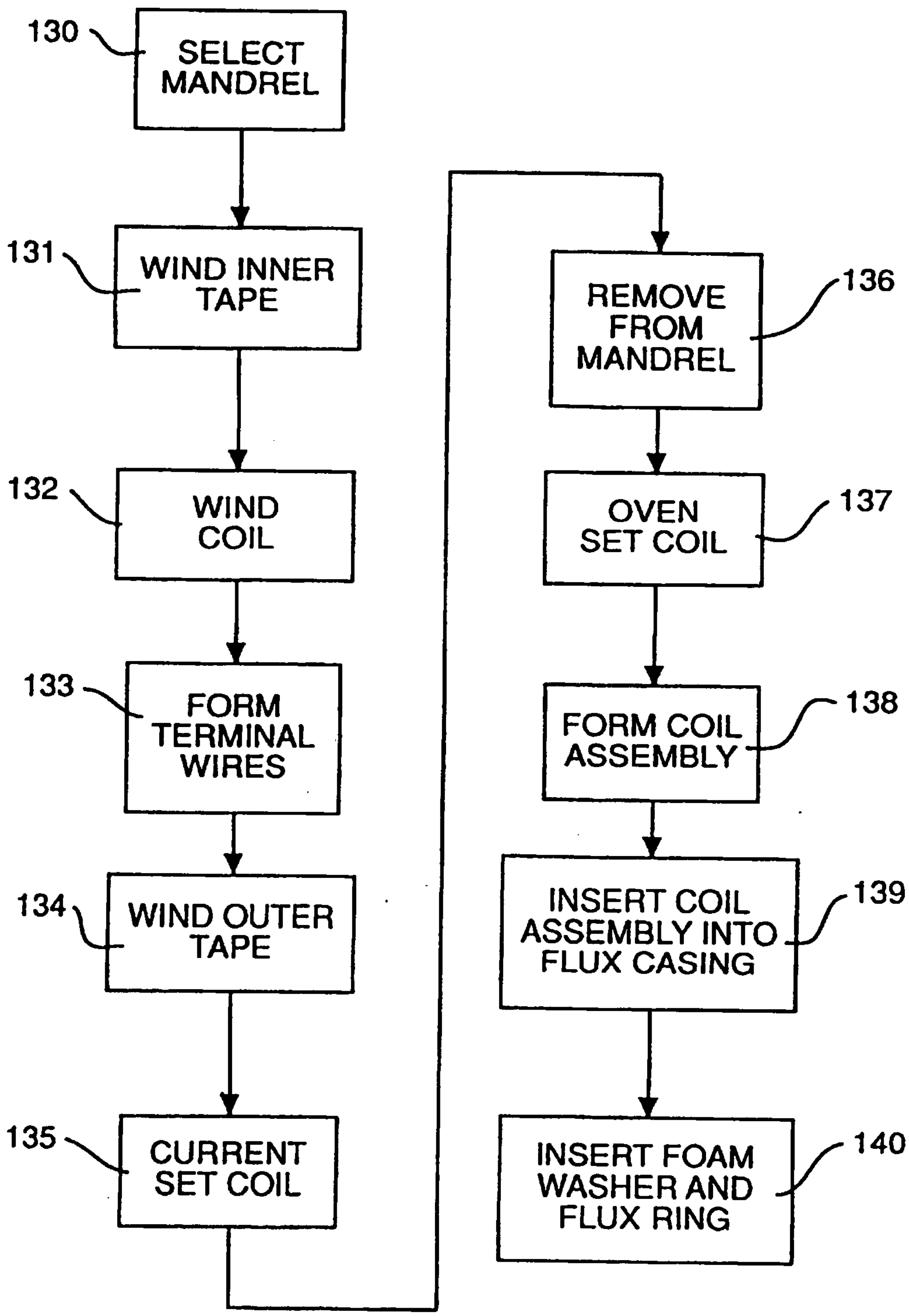


FIG. 7F

FIG. 9

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SELECT MANDREL
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WIND INNER TAPE
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WIND COIL
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FORM TERMINAL WIRES
134
WIND OUTER TAPE
135
CURRENT SET COIL
136
REMOVE FROM MANDREL
137
OVEN SET COIL
138
FORM COIL ASSEMBLY
139
INSERT COIL ASSEMBLY INTO FLUX CASING
140
INSERT FOAM WASHER AND FLUX RING

FIG.8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/03839

A. CLASSIFICATION OF SUBJECT MATTER
IPC(6) :H01F 5/00, 7/08; B32B 31/00
US CL :335/282; 336/192; 156/274.2
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
U.S. : 335/255, 282, 299; 336/192, 198; 156/55, 169, 173, 272.2, 274.2
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US, A, 4,728,916 FONTECCHIO, ET.AL.) 01 March 1988, SEE FIGS. 12-14.	1,2
Y	US, A, 4,639,703 (METCALFE) 27 January 1987, see col.9, lines 15-20.	15
Y	US, A, 4,228,415 (SCHANTZ) 14 October 1980, see the entire document.	1-21
Y	US, A, 2,449,438 (WISEGARVER) 14 September 1948, see the entire document.	1-14, 16-21

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 APRIL 1997	22 MAY 1997
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer ALLEN MACDONALD Telephone No. (703) 305-9646

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